

System  
Development  
Corporation

Technology  
Series

# Information Retrieval



# INFORMATION RETRIEVAL





323 (MOADS) U-98





# THE INFORMATION PROBLEM



It has become a truism in recent years to say that science and technology, government, business and industry, in fact, all the professional fields, are confronted with an acute problem in information: the vast amounts of data being generated in what has been described as an "information explosion" that are in critical need of organization for rapid and accurate accessibility.

In addition to a multiplicity of private organizations working in the field, the United States government has shown increasing concern. Committees of both houses of Congress have explored the problem. A special panel of the President's Science Advisory Committee spent more than a year studying the responsibilities of the technical community and the government and identifying the problems in information handling that have been magnified by the accelerating growth of science and technology.

## PARTICIPATION IN THE FIELD

Millions of dollars a year are already being spent by industry as well as government agencies on the development of assorted information retrieval systems. System Development Corporation has been directly concerned as a developer and user of information and as an organization that assists



government and educational organizations in the effective use of advanced information processing techniques. Its work in the specific field of information retrieval dates back to 1958.

#### AN AGE-OLD PROBLEM

Despite the current emphasis on the need for information retrieval systems, the problem of storing and retrieving knowledge is an ancient one. It could probably be traced back to the cave paintings made some 25,000 years ago when, unknowingly, man took the first step toward recording experience and communicating it beyond the range of his own voice and the span of his own lifetime.

#### EVOLUTION OF INFORMATION RETRIEVAL

For thousands of years thereafter libraries acquired, organized, stored, and made accessible on demand the written products of human experience; information retrieval, as a modern concept, was first thought of in terms of simply storing and retrieving documents. However, the growing volume of publications—in 1960 the world's technical literature was estimated at one to two million papers a year appearing in 30,000 journals—has pressured the technical community to devise ingenious schemes for document retrieval. But document retrieval alone is not enough: a technical specialist really needs specific information contained within documents, not merely the undigested bulk of a body of published literature.

As a result, the problem of information retrieval has become considerably more sophisticated. It involves not only the development of advanced equipment, but also profound conceptual questions on the definitions of "information," "fact," and the various uses of both.

#### HARDWARE

Great advances have been made in solving many of the physical aspects of the problem. A variety of hardware devices is readily available, ranging from simple perforated card equipment to elaborate digital computers and



special-purpose search and processing gear. Vast improvements have been made in storage mechanisms and there has been significant progress in the development of devices, such as optical character readers, that will permit the rapid and economical preparation of information for machine processing.

### TECHNIQUES

The most difficult problems are posed by basic concepts. A major challenge—though it appears deceptively simple—is learning how to label information items so that they are not only adequately described, but also differentiated from other, possibly similar items. Another critical problem is learning how to help the user to ask the right questions. Often he is unable to state precisely the information he is seeking and his initial search request does not prove fully productive. Systems are needed that can describe their data holdings to the user in such a way that he is able to browse for leads and search paths which may help him locate specific items of interest.

There are also serious difficulties in the area of information distribution, or dissemination. Specifically, the problem is to characterize the interests of individual information users in such a way that pertinent information can be selected from a stream of documents and brought immediately to their attention.

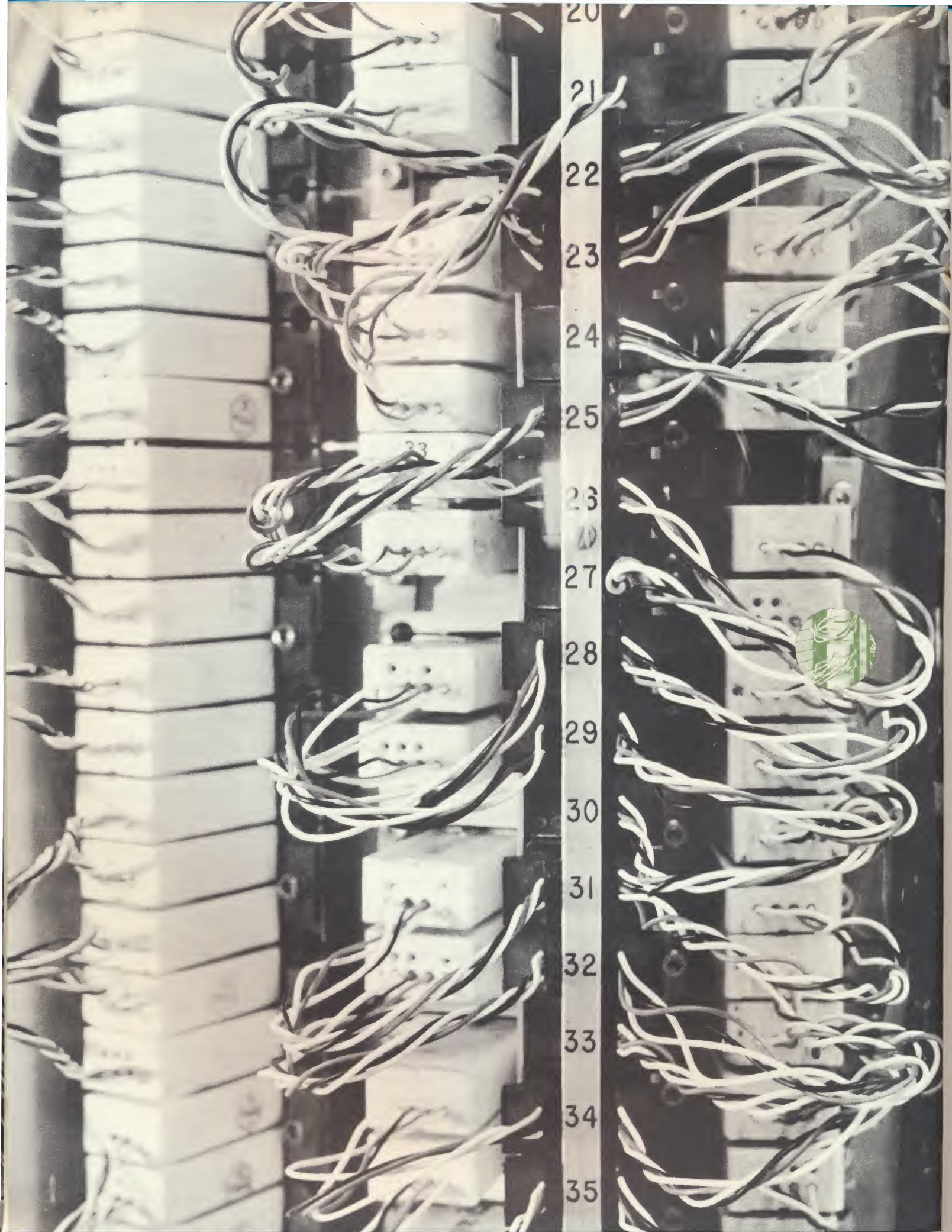
### INFORMATION MANAGEMENT SYSTEMS

In the process of broadening the basic concepts of the field, the term “information retrieval” has become too restrictive to encompass the full scope of system functions. The more inclusive designation of “information management” has been adopted at SDC.

### INFORMATION MANAGEMENT

What is information management? Stated most simply, it is the establishment and utilization of effective procedures for controlling the generation, processing, flow and use of information. Procedures can be manual or machine-aided, although they are most commonly considered as involving machine aids.







# HISTORICAL DEVELOPMENT



---

## DOCUMENTATION

In the SDC view, information management technology is the outgrowth of three separate streams of activity. The first is that of documentation, best represented by the library. The object of interest of this field has traditionally been the document—a book or treatise—and the emphasis has been largely on archival operations. Timeliness has not been an overriding consideration. Much of the literature on the subject of information retrieval and automated literature searching has been generated by the documentation activity.

## BUSINESS SYSTEMS

A second major contribution to information management technology has come from the area of business operations. Since the late 1930's, machines have been used extensively to expedite tasks connected with sorting, storing, and retrieving recorded business information. Insurance records management is typical of this type of application. The business community has been primarily responsible for pioneering the use of large semiautomated data files. The information in these files, unlike that with which libraries are concerned, is principally numerical, generally concise and usually requires fairly timely processing to be of value. Some government



operations, like the maintenance of labor statistics and census data, may be considered part of the same stream of activity.

### MILITARY SYSTEMS

In the middle of the 1950's a third major influence became significant. The digital computer, which provided faster and more powerful information-handling capabilities than had ever been available before, began to be used extensively as the central element of large real-time military information processing systems. The first and largest of these was the SAGE (Semi-Automatic Ground Environment) air defense system, which used a network of large digital computers to process thousands of air defense events on virtually an instantaneous basis.

Computer-based military systems, like the business records systems, work primarily on concisely stated, well-formatted information. They differ from business systems primarily in terms of the complexity of the operations they perform and in their extreme speed of operation. For example, SAGE filters and organizes thousands of bits of data every few seconds, distributes it selectively to individual operator positions, collates and compares new and stored data, and displays different aspects of the air picture on command. The system also provides the human operators with considerable assistance in exploring decision situations and the choice of alternative courses of action.

Modern-day information management systems reflect these three streams of activity and utilize many elements of each. The enormous range of possible system requirements poses very difficult challenges for the equipment manufacturer, the developer of information-handling techniques, the designer of information management systems, and the user of these systems. Current systems must often be geared to deal both with natural language and with numerical data; with complete documents and with individual facts; with archival-type storage and with small dynamically changing files; with immediate information distribution and with retrospective search; with broad generic searches and with spot questions. It is clear that the current state-of-the-art has yet to provide completely satisfactory solutions to these problems.





## MILITARY APPLICATIONS



---

### SAC CONTROL SYSTEM

The information management aspects of the SAGE System—for which SDC has done the computer program design and development—have already been mentioned. Information management plays an important role in another major computer-based military system on which SDC is working, the Strategic Air Command Control System (SACCS). To operate effectively, SAC requires current information on the condition and disposition of its global forces, world-wide weather conditions, and the location of critical enemy forces and facilities.

The primary form of response to interrogation in the SAC Control System is through displays—that is, outputs whose format is predetermined, but whose content is variable. These displays, developed from basic data kept in the computer's peripheral storage equipment and continually updated by inputs from SAC units and other systems, are designed to meet the known information needs of SAC decision-makers.

In the SAC Control System, as in documentation systems, it is exceedingly difficult, if not impossible, to anticipate all information needs. Instances occur in which the basic information has been stored, but no specific output

for it has been designed. As part of its work on this system, SDC has developed data retrieval programs which allow the SAC user to request and receive printouts in various formats of any data defined in the system's data base.

### INTELLIGENCE SYSTEMS

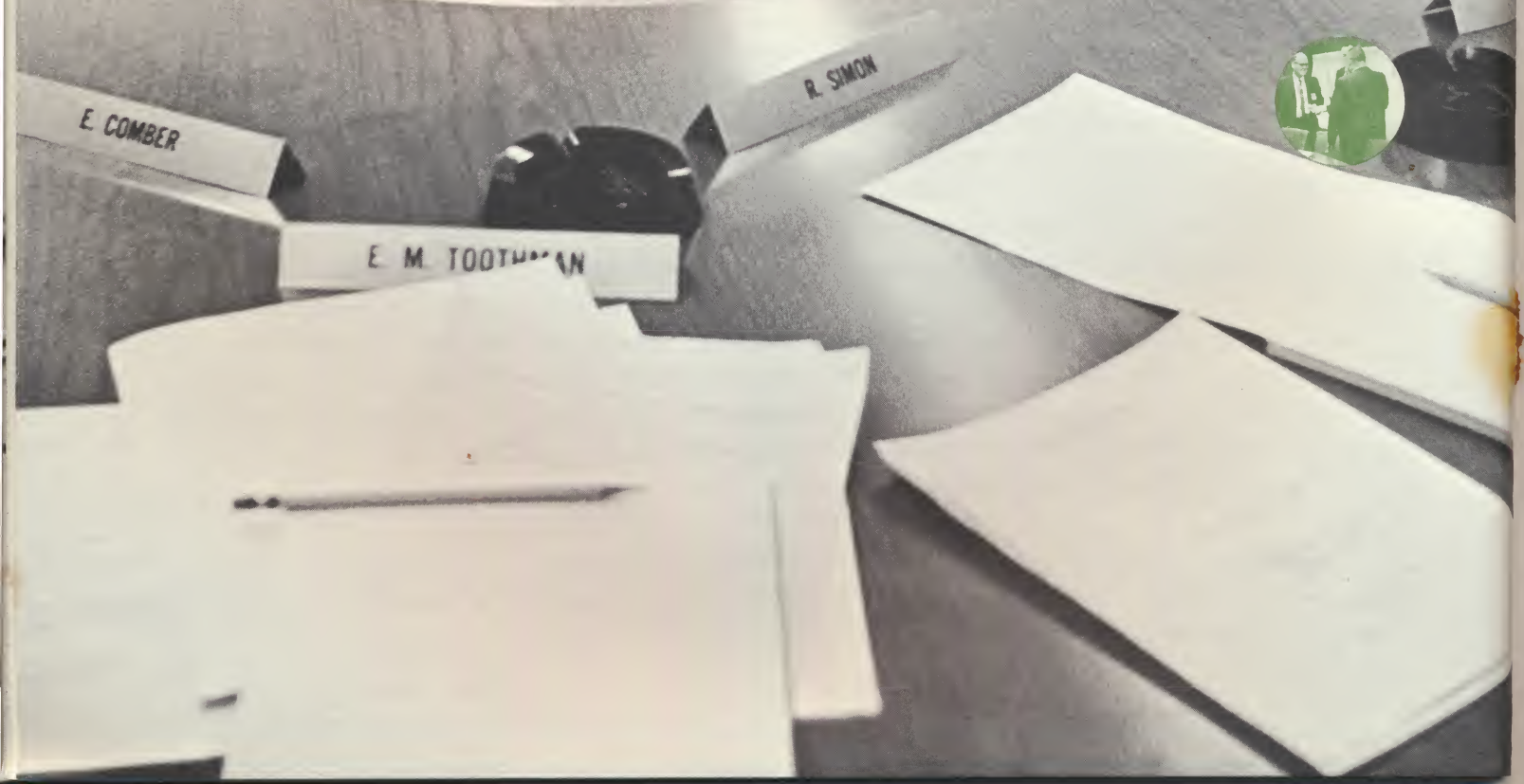
Intelligence systems present particularly complex information management problems because these systems, more than the military command or control systems, deal primarily with natural language data. Many of these systems must cope with such diverse language materials as foreign journal and newspaper articles, translations, abstracts, brief teletype messages and standard intelligence reports. The range of formats, variety and content, and the requirements for data correlation and for access at many levels of generality and specificity have required the design of unique thesaurus-building programs and other language processing procedures.

### DATA BASE MANAGEMENT

In most large information management systems, organization of the data base—the data on which the system operates—is an extremely important activity. Data bases vary in storage media and in the characteristics of their items. The ease with which the data base can be “loaded” and the flexibility with which it can be searched, manipulated and updated determine to a large extent the operational capabilities of the system.

In its work for the Department of Defense Damage Assessment Center, SDC developed a data base system to store and process the extremely large repository of data needed for rapid damage assessment. The problem was complicated by the fact that much of the data, which had to be obtained from other systems, was in a variety of formats. It was necessary to store the information in the form required by the user's system, as well as organize it for efficient utilization. The data base system designed to meet this requirement is parameter-controlled. Thus it provides the flexibility necessary for constructing, loading and manipulating the information from these different sources. Further, the system allows the user to specify the required actions in understandable English.







## NONMILITARY APPLICATIONS



---

Equally as interesting as the computer-based military systems are the newly emerging information systems in the fields of medicine, education, urban planning, law and scientific and technical documentation.

### MEDICINE

For more than four years, SDC has been engaged in research and development of information management systems for the medical sciences. Since 1960 SDC and the Veterans Administration (VA) have been collaborating on the development of an integrated information management system for the Department of Medicine and Surgery. SDC is also designing an information processing network for a vast medical center under construction in San Juan, Puerto Rico.



In one phase of the VA program, SDC established and operated a prototype medical research support center to determine manual and computer methods for recording, storing, retrieving, and analyzing research data. In another part of the program concerned with the handling of medical records, a computer-based system that rapidly accepts, processes and retrieves patient data in a simulated hospital setting was successfully developed and demonstrated.

#### EDUCATION

More and more school districts and institutions of higher learning are installing electronic data processing systems for the management of educational data. This development, coupled with the already extensive use of electronic accounting machines in the registrar and business offices, seems to portend a major technological change in school system operations. It is increasingly evident, too, that information processing techniques will extend into the classroom facilitating innovations in instructional techniques.

The research and development at SDC in the field of education has underscored the emphasis on automatic information processing. In 1960 SDC designed and constructed a computer-based laboratory to study automation in school systems. In this laboratory research has been conducted in the use of teaching machines, rapid information retrieval systems, and programmed TV lessons. The goal has been to develop the physical facilities, instructional programs, and information management techniques necessary to permit each student to progress through a curriculum at a rate consistent with his abilities and interest.

SDC has been engaged in defining and analyzing several school systems in the state of California, and in the case of one particular school, has been involved in designing the information processing system. The California State Department of Education and SDC are cooperating on the development of a computer model of a secondary school set in the context of a district, regional and state data-link network. This model will be used for further systems analysis and design work. SDC has also been working with the United States Office of Education (USOE) to analyze the data collection procedures

connected with several major educational programs. The intent of this study is to revise the information systems operations of the USOE and to establish a central data bank for the management of educational information.

#### METROPOLITAN GOVERNMENT

Metropolitan governments have complex problems in information management. These problems concern three major functions: operations, planning, and research. In their day-to-day operations, the individual city departments such as Public Works, Building and Safety, Health, Police, and Fire, as well as the different administrative agencies such as the city clerk, controller, and administrative officer, must deal with a great variety of information about businesses, real and private property, people, and events. The problems of acquiring, maintaining, and using this information have multiplied as a result of the rapid growth of metropolitan areas.

Urban planning has become singularly complex, with a pressing need for information on land use, facility requirements, and socioeconomic data. Information for urban research has also become an important requirement. The relationships among demographic behavior, economic characteristics, and residential, industrial, and transportation facilities of a metropolitan region are not well understood. Yet these relationships represent the base upon which metropolitan planning and operations rest.

One method for solving the information problems of metropolitan operations, planning, and research is to develop urban information systems that are integrated information management systems for given metropolitan regions. At present, SDC is conducting a study of a generalized urban information system, examining the information needs of decision-makers and other concerned individuals, potential system designs, cost/feasibility tradeoffs, and recommended steps for the development of a specific system.

#### LAW ENFORCEMENT

The problems of law enforcement information processing are becoming particularly severe as population expands and crime and traffic incidents occur at an ever faster rate. For some time, SDC has been working with the



law enforcement community to determine how information management technology can be applied to law enforcement problems.

A committee of the California Peace Officers Association is exploring the feasibility of a state-wide law enforcement information system to provide the field officer with rapid access to files containing wants and warrants for specific persons, stolen vehicle data, criminal records, and other identification information. SDC is participating in the work of this committee.

The other activity is concerned with the retrieval and analysis of crime information for purposes of general patrol distribution and investigation of specific crimes. In the processing of crime reports, present techniques employ precoded summaries abstracted from the original reports. Some potentially useful information is lost in the process. SDC is experimenting with natural language computer programs that will permit the storage and retrieval of crime reports in their original, full-text form.

#### LAW

The legal profession has used highly developed research aids for years, and over the past decade has turned increasingly to automated data processing. A project was begun in the spring of 1961 at SDC to determine the potential and the problems in applying automated data processing to the operations of trial courts in general and to the Los Angeles Superior Court in particular. To date the study shows that simple data processing aids can assist in several areas: filing, indexing, and maintaining case files; preparing statistical and management reports; managing the court calendar; determining diagnostic patterns in the events that lead to marital complaints; and processing of data related to those in custody. This project is a joint undertaking of the court, the UCLA Law-Science Research Center, and SDC.

A second project was begun in 1962 to investigate the utility of machine-prepared indexes of appellate decisions (using the word, "indexes," in a broad sense). It is felt that such indexes, when published, will provide those who cannot afford to use a computer with at least some of the benefits of computerized legal search. Experimental computer routines which index, concord, abstract, edit, or list several forms of concordances have been prepared.



## SCIENTIFIC AND TECHNICAL INFORMATION

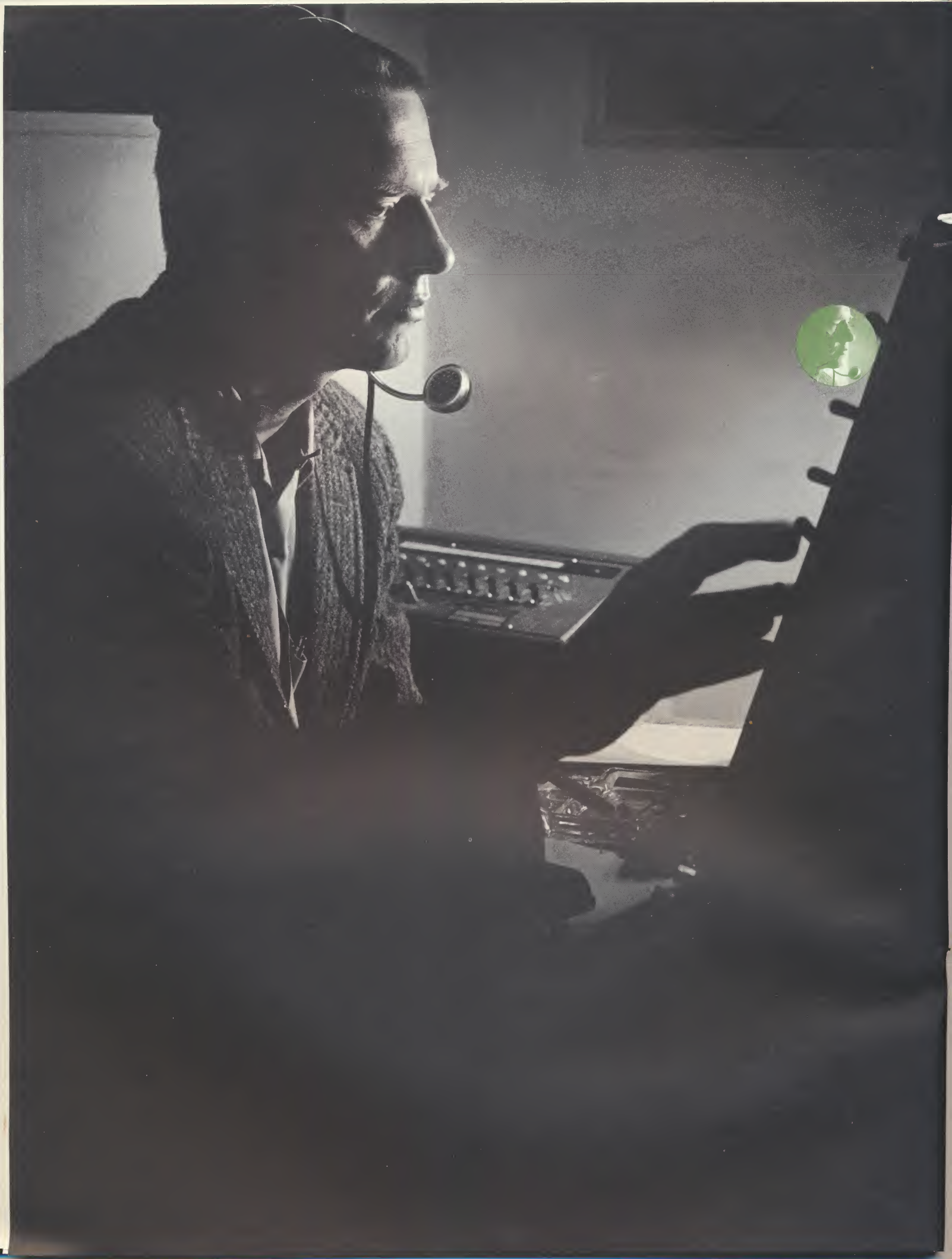
Probably the most urgently needed work in information management is in the area of scientific and technical information. The President's Science Advisory Committee concerned itself chiefly with this area and with the need to establish better management of the generation and flow of scientific and technical reports. SDC is working with the Science Information Exchange in Washington, D.C., exploring the use of the natural language of the reporting scientist to relate and retrieve research reports.

The Science Information Exchange maintains a clearing house for current research in the biological and physical sciences. Research reports from the current files of the exchange are being used in an experiment to compare full-text machine processing with present manual procedures for locating (i.e., retrieving) research reports related to specific queries. Machine-produced responses will be compared with actual operating results provided by the staff of the exchange. Computer programs developed at SDC for the handling of natural language data will be used extensively in this experiment.

## IN-HOUSE DEVELOPMENT AND USE

Information-handling techniques are being applied in SDC's own operations. This use not only provides a valuable service, but also permits the techniques to be carefully evaluated in an operational setting.

An example of in-house development and use is the SATIRE system of Semi-Automatic Technical Information REtrieval. Developed several years ago, SATIRE is based on existing machine capabilities and techniques for document retrieval. Utilizing EAM equipment, SATIRE produces all library cross-reference card catalogs, preprinted cards for an automatic charge-out system, selected bibliographies, library indexes for publication, accession lists, and author inventories. A computer-based version of SATIRE yields the same products, but provides the advantage of tape storage, simplified updating and obsoleting procedures, a higher degree of accuracy, more complete indexes, and much greater speed of operation. The system, developed to serve both scientists and librarians, is in operation in two of SDC's divisions.





# RESEARCH



---

## NEED FOR RESEARCH

Some of the applications of information processing techniques described have existed for many years; others are barely beyond the research stage. The information management field, like most others, has made exceptional headway in some directions; additional work is needed in other areas that are currently the subject of a substantial research effort.

## CLASSIFICATION AND INDEXING PROCEDURES

One series of SDC studies is examining the derivation of automatic and semiautomatic procedures for indexing, classifying, and abstracting documents. Initial results have shown that mathematically derived classification systems are useful in structuring large information repositories. Researchers are now analyzing new sets of documents to determine the reliability and consistency of factors previously derived and reported. Machine (i.e., automatic) classification of documents into derived categories is being compared with human classification.

As part of this work, SDC is studying the feasibility of representing the contents of files and libraries in "association maps" and "hierarchical maps." These representations, generated automatically on the basis of computer analysis of word associations in text, appear to have considerable promise as aids in information retrieval.

## LINGUISTICS AND COMMUNICATION ANALYSIS

A second series of projects deals with linguistics and communication analysis. A much-used device in natural language discourse is the abbreviation of a long phrase in a given text sentence by a single word or short phrase in a later sentence of the text. This practice, while necessary for compact writing, produces difficulties in the machine processing of language. On the basis of a study of abbreviating phrases in a large corpus of scientific writing, tentative rules have been formulated for recognizing certain kinds of abbreviating phrases and locating the phrases in preceding sentences which they abbreviate. These rules are being coded for incorporation into mechanical paraphrasing and abstracting routines.

### "FACT RETRIEVAL"

A third group of projects includes a study of "fact retrieval." An attempt is being made to ascertain the conditions at the interface between man and computer that will permit human requesters to communicate satisfactorily with a file of information elements. If adequate man-machine symbiosis can be achieved, it should be possible to supply the requester with the facts he needs, rather than with the document containing these facts. Some of the aspects being considered are the development of suitable request and storage languages, the formulation of complex information requests, and the potential of joint human-computer resolution of these problems.

### NATURAL LANGUAGE PROCESSING

Extremely difficult to develop are computer programs that can process natural language information as if the meaning of the words were understood. Nevertheless, the information management field needs programs of this sort if it wishes to relieve the scientist, technician, businessman, or military commander of much of the burden of present-day information-handling procedures. One of SDC's research projects, known as Synthex, involves the development of computer programs that will enable a computer to accept a question in natural language, to analyze the syntax and the logical dependency relations of the question, to perform the functions necessary in searching the memory banks for the desired answer, and to output that answer in natural language.

To simulate human language behavior on a machine, Synthex must describe what a human does when he is presented with a question, finds or develops the answer from a relatively vast body of intellectual experiences, and states that answer. Something like this process has been systematized and translated into a complex program of machine instructions. The program has operated successfully on several types of literature and is now undergoing additional refinements to permit the drawing of inferences about information in the file. While the full application of such a capability is probably some years away, the present research is highlighting problems that must be solved in the meantime.







# FUTURE OF INFORMATION MANAGEMENT



The next ten years are destined to stimulate even greater concern with information management. It is expected that by 1965 the expenditures on such systems will be more than 100 million dollars a year and will double every few years thereafter.

Advances in general- and special-purpose equipment will provide a stimulus for new information management applications. The cost per unit of information storage and processing equipment can be expected to decline and to bring powerful machine aids within the reach of small organizations.

New capabilities in information management techniques can also be anticipated. Systems will be developed that can provide information users with specific facts, rather than the body of published literature. These systems will help to select, compress, and organize material in order to conserve one of the nation's most valuable resources—its highly trained scientific and technical personnel.

The tremendous economic, scientific and technical progress since World War II, and the pressing need for accurate, high-speed, information management systems to support human decision-making, show no signs of tapering off. In the public interest, SDC will continue its efforts to contribute to the development of this important field.





---

Corporate Offices:	2500 Colorado Avenue, Santa Monica, California 90406
Air Defense Division:	2500 Colorado Avenue, Santa Monica, California 90406
	Liaison Office: 1719 E. Bijou Street, Suite 1030, Colorado Springs, Colorado 80909
Command Control Division:	45 Hartwell Avenue, Lexington, Massachusetts 02173
	SACCS Department: 567 Winters Avenue, Paramus, New Jersey 07652
Development Division:	2500 Colorado Avenue, Santa Monica, California 90406
	Dayton Facility: 26 West Nottingham Road, Dayton, Ohio 45405
Washington Division:	5821 Columbia Pike, Falls Church, Virginia 22041
New York Office:	350 Fifth Avenue, Suite 5701, New York, New York 10001
Washington Office:	1725 Eye Street, N.W., Suite 702, Washington, D.C. 20006

---

System  
Development  
Corporation

Technology  
Series





System  
Development  
Corporation

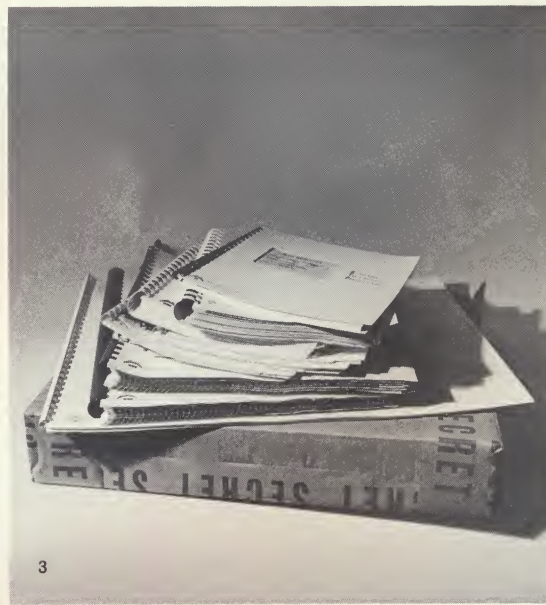
Technology  
Series

# Simulation



# Simulation





**Photo 1:** The crew of a simulated air defense radar site in the early Systems Research Laboratory perform in the artificial setting as if in a real air defense situation; scientists view the procedures from observation deck above. **Photo 2:** Air Force personnel "conduct air defense" in a simulated laboratory radar site. **Photo 3:** The many simulation aids required to conduct a single problem include films, maps, flight reference lists and instruction manuals.



# Introduction to the Technology

## Origins

A little more than a decade ago a team of scientists were searching for clues to the behavior of man-machine systems. In what had once been a pool hall in Santa Monica, California, they built a replica of an air defense radar site that then existed in the Seattle area. Initially, this simulated complex was manned with college students, later with Air Force personnel. The scientists then devised a way to make it appear to the crews that an air attack was taking place. Because it was a contrived, simulated attack, the experimenters knew the exact details of the situation confronting the crews and could observe carefully how they handled the attack. Then, within minutes after the simulated battle, a "debriefing" session was held in which the crews were told what they had been up against. The crews, in turn, analyzed what they had done about it. Compared with crews engaged in actual air defense operations, the laboratory crews not only achieved the same degree of efficiency, but after participating in a series of these experiments, tripled the problem load they could handle without loss of efficiency.

It had not been the intention of the experimenters to train the crews, yet they discovered how crews can achieve remarkable performance under stress in very complex situations. This discovery was developed into the technology of the System Training Program, tried out in operational radar stations in Southern California, and then extended across the continent. Operational crews, air defense divisions, air defense forces, and the entire command were able to exercise themselves using their actual equipment against battle problems of many varieties and to become "battle experienced" without scars—at a fraction of the cost of live exercises.

This is the historical basis of a true extension of the technology of simulation. System Development Corporation pioneered and developed this extension of the technology in the field of air defense and made its first major application



to the problems of system training. Today, however, its applications far exceed this early limited use. It may be applied, in fact, to virtually any complex, man-machine information-processing system, whether the system is intended for military command and control or for information management, in such fields as education, medicine, metropolitan government, and the like. Additionally, it may have as its objective, system analysis, design, testing, evaluation, or training. Because it realistically incorporates the operations engaged in by people in live-system functions, SDC scientists have named it *operations simulation*.

While operations simulation is not generally well known, there are other forms of simulation which are more familiar because of their widespread use in the defense-systems industry.

#### Physical Simulation

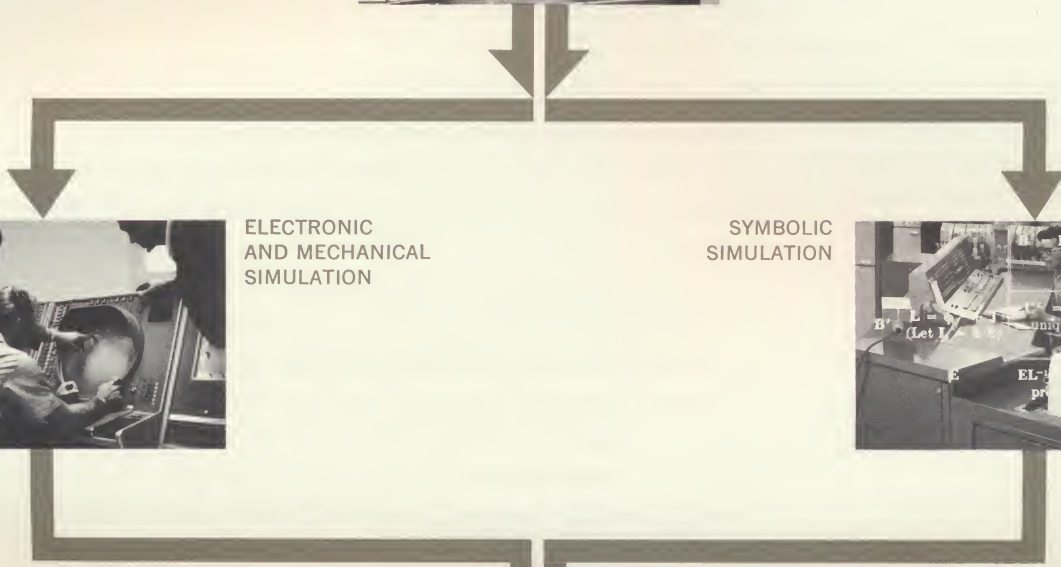
Following World War II, simulation became an integral part of the aircraft industry, and now plays an important role in advanced aerospace programs. Perhaps the most common image of simulation, as a result of articles in the technical and popular press, is that of the cockpit simulator—the Link Trainer—of World War II vintage. Since that early use of simulation to train a highly sophisticated performer in a complex machine-based system, simulation hardware products have become diversified and appear in countless applications.

Today's jet pilot trainer is a fantastically detailed and accurate reproduction of an actual aircraft cockpit complete with vibration, noise, and view. Today's Navy submariner practices dives in a simulator equally as detailed as a cockpit trainer. These and other training simulators are inexpensive when compared to the cost of providing equivalent experience using real equipment. They also afford an essential ingredient—safety—which money can't measure.

#### Symbolic Simulation

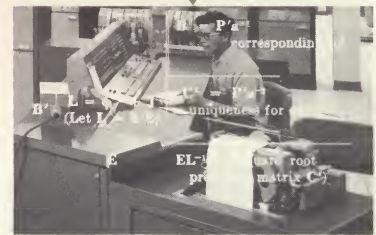
A complementary form of simulation became widespread in the field of operations research at about the same time. In this form of simulation, the behavior of the system to be simulated is deduced from its formal description; all aspects of the system are then reduced to logical decision rules that can be expressed as symbols and formulae and, usually, programmed for a computer. An exacting, critical instance of this form of simulation is employed in the design of today's complicated aircraft and space vehicles. While the wind tunnel is still used, it is now equally commonplace to "fly" proposed new aircraft and space vehicles in a computer, both to save time and to evaluate design characteristics that can't be completely tested in wind tunnels, e.g., satellite re-entry. While operations research people think of this activity simply as simulation, at SDC it is contrasted with operations simulation and with the hardware techniques inherent in physical (cockpit) simulation by naming it *symbolic simulation*. This form of simulation is often algorithmic in character.

# MANUAL SIMULATION



## ELECTRONIC AND MECHANICAL SIMULATION

## SYMBOLIC SIMULATION



## OPERATIONAL

## SIMULATION



Figure 1—Operations simulation, involving a variety of simulation modes.



Symbolic simulation is also the basic vehicle for the now classical war games that have taken on a new look with the aid of computers. These games have become highly complex, involving international situations requiring the most intricate manipulation. Their results are used in preparing war plans and in helping to determine new weapon system requirements for the country's defense. Development of this computer war gaming technology has also been applied to civilian pursuits; a popular form is the business management game.

Many of the more recent applications of simulation involve intricate combinations of symbolic and hardware replication. Thus, the cockpit trainer has been expanded to include certain "flight conditions" external to the man-machine interface such as weather conditions and flight instructions.

#### Operations Simulation

The state-of-the-art of the newer operations simulation often goes beyond this, permitting simulation to be used within *operating environments*, wherein human participants use their normal equipment, but are provided any necessary "embedding conditions" such as space, air attack, national economy, nuclear exchange, emergency failure, geo-political circumstances, and the like.

Operations simulation can deal with hardware, command decisions, human interaction, operating procedures, situational change—in fact, all the important factors operating in and about a system—in such a way that inputs are identified, performance is observed and measured, and outputs are recorded. Here, then, is a significant extension of the simulation technology that provides powerful means of assisting in the design, development, evaluation, and improvement of total systems.

Applications of the techniques of operations simulation may range from a very small, compact unit, such as an interaction sequence between two individuals, or the activities of a single classroom, to the vast, far-flung functions of a military command and control system. SDC simulation studies have included both extremes and have been conducted with or without the use of a computer, as appropriate.

While a computer is not necessary in some operations simulation studies, or in all stages of these studies, the more comprehensive forms of simulation would be impossible without the aid of a digital computer. The computer makes it possible to process information at a rate never before equalled. The amount of computation involved in the operations of a major command and control system can be staggering. Twenty-six computers were necessary in the SAGE air defense system; only one of them could process—in just 24 hours—all of the annual income tax returns filed in this country. Without these powerful central processors, operations simulation could not have been used in SAGE; however, lesser forms of simulation could not have met the crucial training and evaluations problems of this system.

## Man-Machine System Applications

Not only has the development of the computer made possible greatly expanded simulation technology, but the inclusion of computers in complex man-machine information processing systems has greatly increased the area of application of simulation. Though information processing systems are not new, it is only since World War II that the principles of information theory have been derived pointing to the combination of high-speed communication and computation equipment with the decision-making flexibility of the human being.

Today's man-machine information processing system, such as a military command and control system, is composed of three general elements: hardware—such as communications and display equipment and the computer; personnel—such as operations, maintenance, and support staffs; and system software—such as computer programs, procedures, and plans and policies.

The association of such highly sophisticated equipment and procedures with men in these systems has raised questions about the proper allocation of functions between machine and man. A computer can be programmed to perform some of the functions that were performed by men in past information processing systems, including making many elementary decisions. Properly programmed, the computer is capable of receiving, remembering, and organizing information in volume magnitudes at processing speeds impossible for men to equal, rarely makes mistakes, and is seldom confused. However, it is difficult to program a computer to be flexible in making decisions in the face of uncertainty (except random decisions), to perceive patterns, draw conclusions, or estimate information from garbled inputs—as men can do. The computer itself can be used to help solve the problem of allocating functions between men and machines.

### Advantages of Simulation

Even before commitment to a system development effort is made, simulation can be used to “war game” the effects of using different strategies and system approaches to the solution of the problem the system is expected to solve. Simulation can aid basic research in information processing, and applied research into devices, procedures, and practices based on information theory. It is also helpful in development, through generation of simulated inputs for testing components and assisting in design decisions. Simulated inputs may be used also for system testing and evaluation and, as noted, in the training of operating and maintenance personnel. After the system is installed and operating, simulation may be used to try out the effects of alterations and improvements and for the detection and diagnosis of system malfunctions.



Computer-based information processing systems, designed to assist organizational decision making, are characteristically one-of-a-kind. The larger and more complex of such systems can ill afford trial-and-error methods in their development and application. Unlike the equally complex aircraft or missile system, they cannot be manufactured whole. Evolution is the fundamental concept underlying the development of these systems; they must *evolve* in capability as the composition and mission of the using organization itself evolves. Under these conditions the construction and evaluation of prototypes is prohibitively expensive; the use of computerized logical and mathematical models becomes a very valuable technique.

While simulation via a computerized model cannot entirely replace physical construction and testing (there may be several inaccurately represented parameters, values, and interactions in the model depending on how close to the state-of-the-art frontier it is) it can aid in eliminating a great many alternatives, isolate crucial factors for further investigation, and indicate failure points, overloads (bottlenecks), and the like.

This new extension of simulation provides other necessary advantages to the system development process. First and most basic is that it meets the need to structure certain real-world circumstances under one's immediate control when, in fact, the actual circumstances are beyond one's control. To note one of many possible examples, the System Training Program in Europe enables allied military personnel to train against simulated attacking aircraft attempting to penetrate their defense from behind the Iron Curtain. Clearly, it is impossible for allied training flights to perform penetrations of Free Europe from this direction.

In addition, simulation may afford significant savings of resources. Among the obvious is the saving of time. Simulation can compress manyfold the time required for real events to occur. Not so obvious is the ability of simulation to expand real time in order to permit detailed analysis of critical situations. Finally, many systems, military ones in particular, are designed to cope with maximum problem loads. Operations simulation allows us to present maximum load circumstances under controlled conditions. These loads could happen in the real world only if the particular form of military conflict, for which the given system was designed, actually occurred.

At SDC—where system research in support of the development of computer-based information processing systems is a major endeavor—simulation constitutes an integral part of the development methodology. In addition, the use of simulation is so important to the training, maintenance, and improvement of these systems that the capacity and facilities for simulation are included in the corporation's designs for operational information processing systems. Increasingly widespread recognition and acceptance of this design requirement have occurred in both government and industry. However, full utilization of the potential power of simulation techniques is still far from realization; active research and improvement of this technology is a prime concern at SDC.

## Constraints in Simulation

SDC, however, is alert also to the pitfalls which indiscriminate use of simulation contains. The more important of these can be stated as cautions:

Simulation must be kept in its proper perspective as a means to an end, rather than an end in itself; it is a tool, not a product. (A sound case can be made for very singular exceptions to this rule, but the valid exceptions are so specialized that the rule has good practical value.) Even though simulation may save its own cost many times over, it is expensive to design, develop, and maintain. If technical elegance of the simulation is ineffectively controlled, cost can quickly become prohibitive. Management controls must be maintained over simulation design just as they are maintained over the development of any operating system.

In initiating the simulation of some object, event, or condition, it is necessary to determine the critical features which are to be represented and to make clear the rationale for selection of these features. This step contains the key to the validity and credibility of subsequent simulation performance results.

Symbolic algorithmic simulations deal primarily with logical data with rigorous adherence to the rules of logic employed; thus certain qualitative considerations may be necessarily avoided. In some simulations, however, it is only if qualitative factors are deliberately included, that a fruitful degree of completeness of the simulation is assured. An algorithmic simulation may widely miss the mark because highly variable human intervention factors, or other political or social factors have been excluded. To generalize: a given simulation problem must be met by applying the appropriate simulation discipline.

The objective of a simulation is to represent some object, event, or condition. If techniques are not at hand to do this adequately, the simulation should be dropped rather than compromising or simplifying assumptions to make them tractable to computation. Operations simulation has met this issue by providing both the technology and the practical means for simulating complex combinations of objects, events, and conditions heretofore deemed beyond the realm of practical analytical treatment.

The most common pitfall in simulation is the failure to anticipate how simulation results will be used. Simulations can produce literally mountains of data. Selection from these data, reduction into summaries, and analyses of significance must be anticipated and, in fact, preplanned. Perfectly good simulations have been known to fail for lack of this planning.

## The Operations Simulation Process

In operations simulation in a laboratory, it is important to delineate clearly that portion of the laboratory system that is under study. A distinction is made between the "experimental system" and the "embedding system": the experimental system is that portion of the laboratory system which exercises direct control over the synthetic environment and which is subjected to



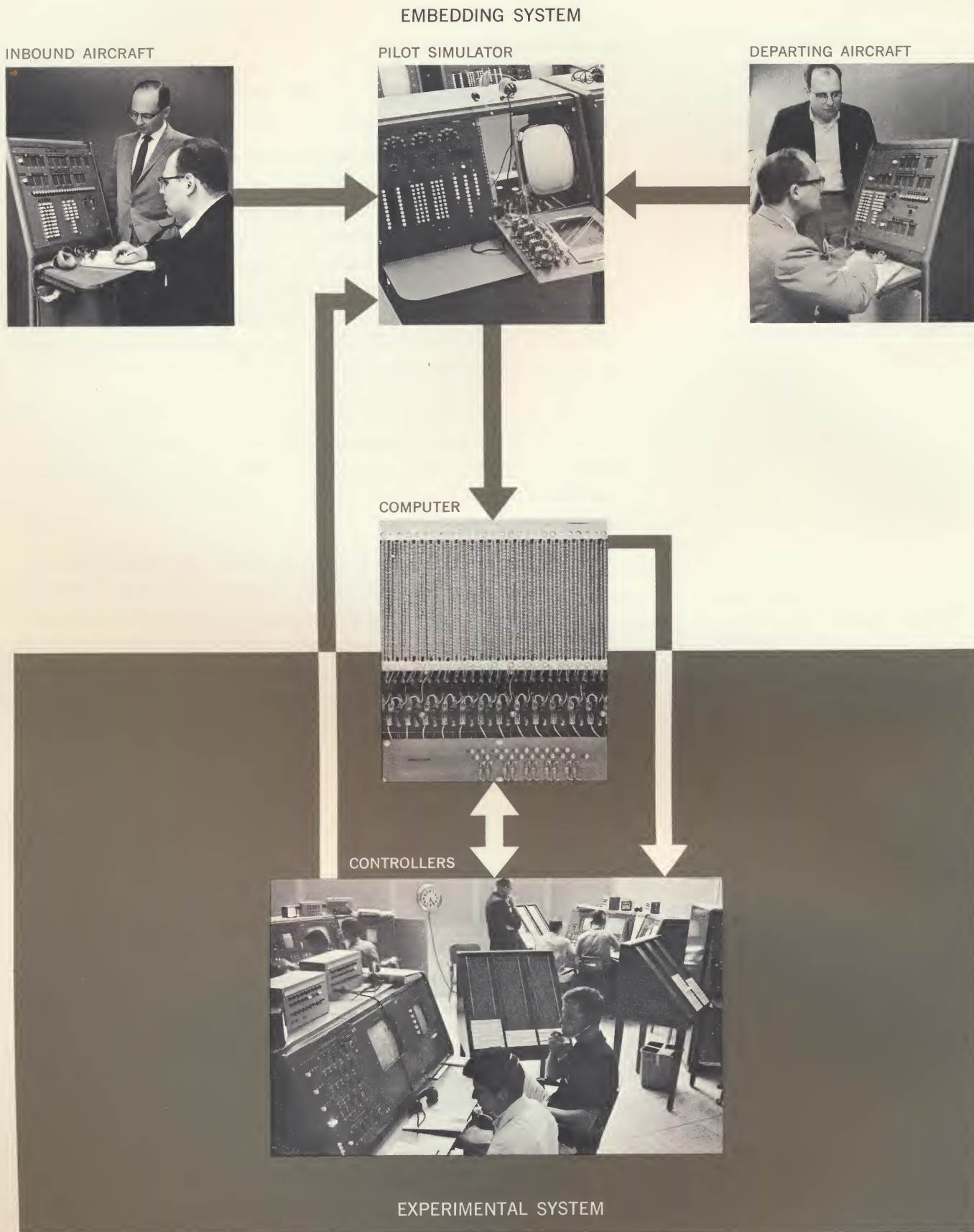


Figure 2—Operations simulation: Terminal Air Traffic Control (TATC) study.

experimental manipulation and analysis; the embedding system provides the means by which this environment is manipulated and the means by which the experimental system maintains communication with surrounding agencies.

The basic information flow through a simulated system is represented in Fig. 2, which represents the experimental system for a recently completed SDC study of Terminal Air Traffic Control (TATC) conducted in its Systems Simulation Research Laboratory. Aircraft were entered into the system by the embedding organization—either as departures originating within the terminal complex or as inbounds (coming in for landing or overflights) originating outside the terminal complex. In either event the information (from a script) was transmitted to a pilot simulator who, in turn, entered some basic parameters on the flight into a console which was linked to the central laboratory computer; the computer actually flew the aircraft and provided feedback to the experimental system by displaying the position and identifying information on the controllers' scopes. Finally, a simulated radio-telephone link between controller and pilot completed the loop, enabling the experimental system to manipulate and control the air traffic.

The computer generally has three distinct functions in such a laboratory system. It generates, updates, and changes data; it operates as part of the control system by maintaining displays and responding to switch actions; it records system performance information.

The design and creation of a man-machine system, as complex as the Terminal Air Traffic Control System, for example, requires considerable planning and exploratory experimentation before a satisfactory model evolves. As a first step, a preliminary system description provides the overall requirements for engineering, programming, human engineering, and operating rules and procedures. Following such preliminary description, a series of design tests are conducted to evaluate the subsystems at various stages of completion in terms of overall system requirements. After several such design tests, the system operation may be explored in a more formal sense through a series of exercises with trained subjects for both the experimental system and the embedding system.

Then, such a model has to be altered and restructured as a result of insights gained from the simulation itself. This, together with specific results from the analysis of the earlier exercises, paves the way for the modification and improvement of the hardware, programs, and procedures in the simulated system before the next series of exercises. Not only is research knowledge gained, but the means are at hand for immediate application to an operating system.

SDC's Systems Simulation Research Laboratory was created in 1961 as an instrument for exploring and advancing theories of system development such as those inherent in the TATC problem. Through the use of real-time operations simulation, the laboratory is making contributions to knowledge, insight, and methods for studying information processing systems in a variety of other application areas.



## SDC Experience in Air Defense

SDC is unique in possessing a long and diverse experience in computer-based simulation; in the field of air defense this experience was acquired over a 12-year period and spans three generations of air defense systems: the initial manual system, the computerized SAGE system, and the third generation digital system called BUIC (Back-Up Interceptor Control).

### System Training Program

As noted earlier, the initial Air Defense Direction Center simulation led to the System Training Program (STP) for manual air defense. From these roots a complex simulation technology evolved to provide packaged problems for field use from a computerized production base. These problem packages were initially produced for air defense divisions (containing several radar sites), then evolved into integrated air situations for larger regions, and finally culminating in continental combat settings to exercise the entire North American Air Defense (NORAD) System. NORAD-wide exercises were initiated in 1958 and continue today.

This kind of simulation required equipment and personnel support over and above computer technology. For example, special equipment was developed to produce radar input films under computer control. Another device, tagged the AN/GPS-T2, was developed by SDC to process radar inputs on the computer-produced film and present them on the radar consoles at manual direction centers. SDC contributed toward the development of an Anti-Countermeasures Trainer (ACTER) to generate jamming patterns on radar inputs for more realistic air attacks. Special scripts, manuals, training aids, overlays, data dictionaries, and maps were produced both manually and by the computer as part of the training package to support the system training exercises. Fig. 3 details the simulation activities involved in a system training mission.

The concept of the original simulated air defense direction center was elaborated into a more general-purpose simulation laboratory which could be adapted to the geography, air traffic, and embedding organizations of any air defense direction center in the country. In this laboratory, called the Indoctrination Direction Center, hundreds of Air Force personnel experienced the System Training Program by learning to deal with simulated problems custom tailored to their own local air defense setting.

### SAGE

The introduction of SAGE, the first computer-based system of air defense, triggered many simulation innovations in response to the new requirements made possible by the AN/FSQ-7, the large, general-purpose computer at the

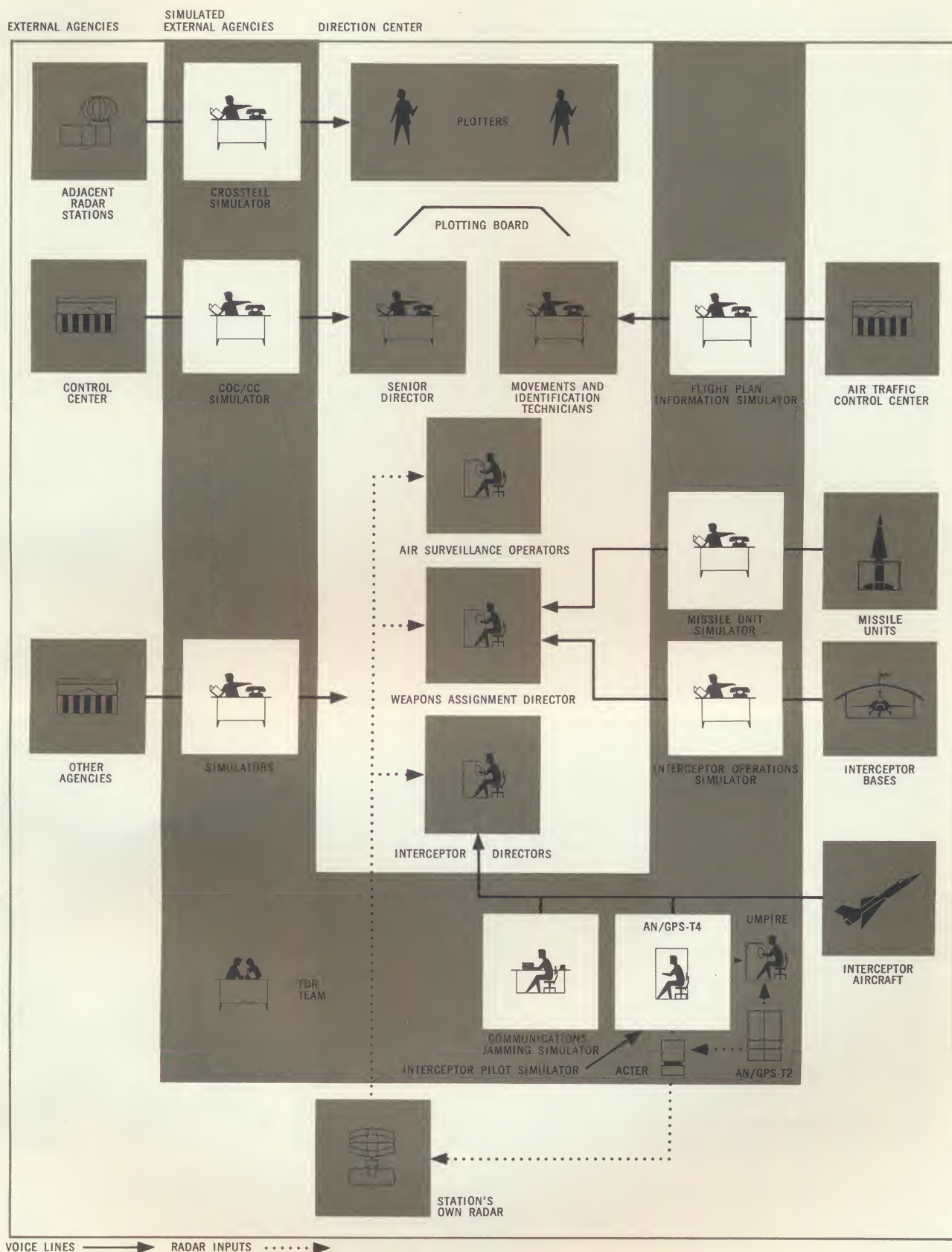
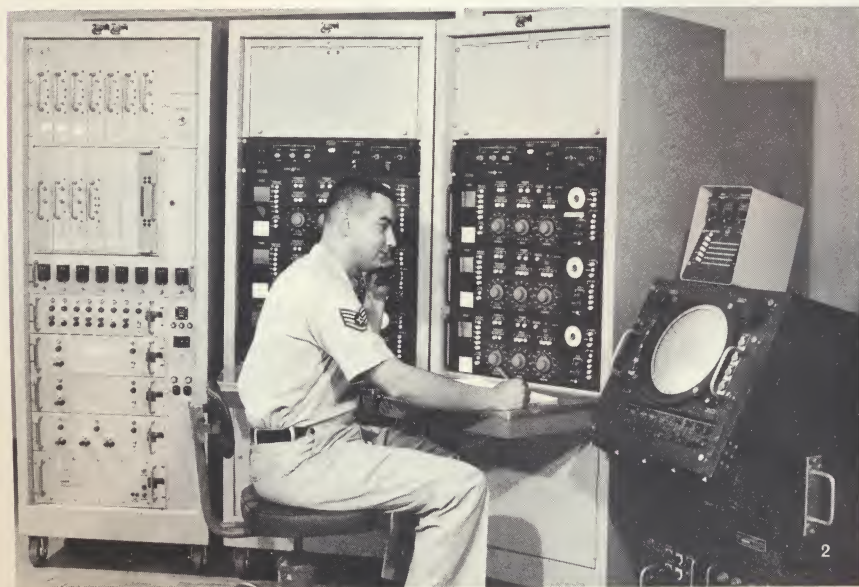
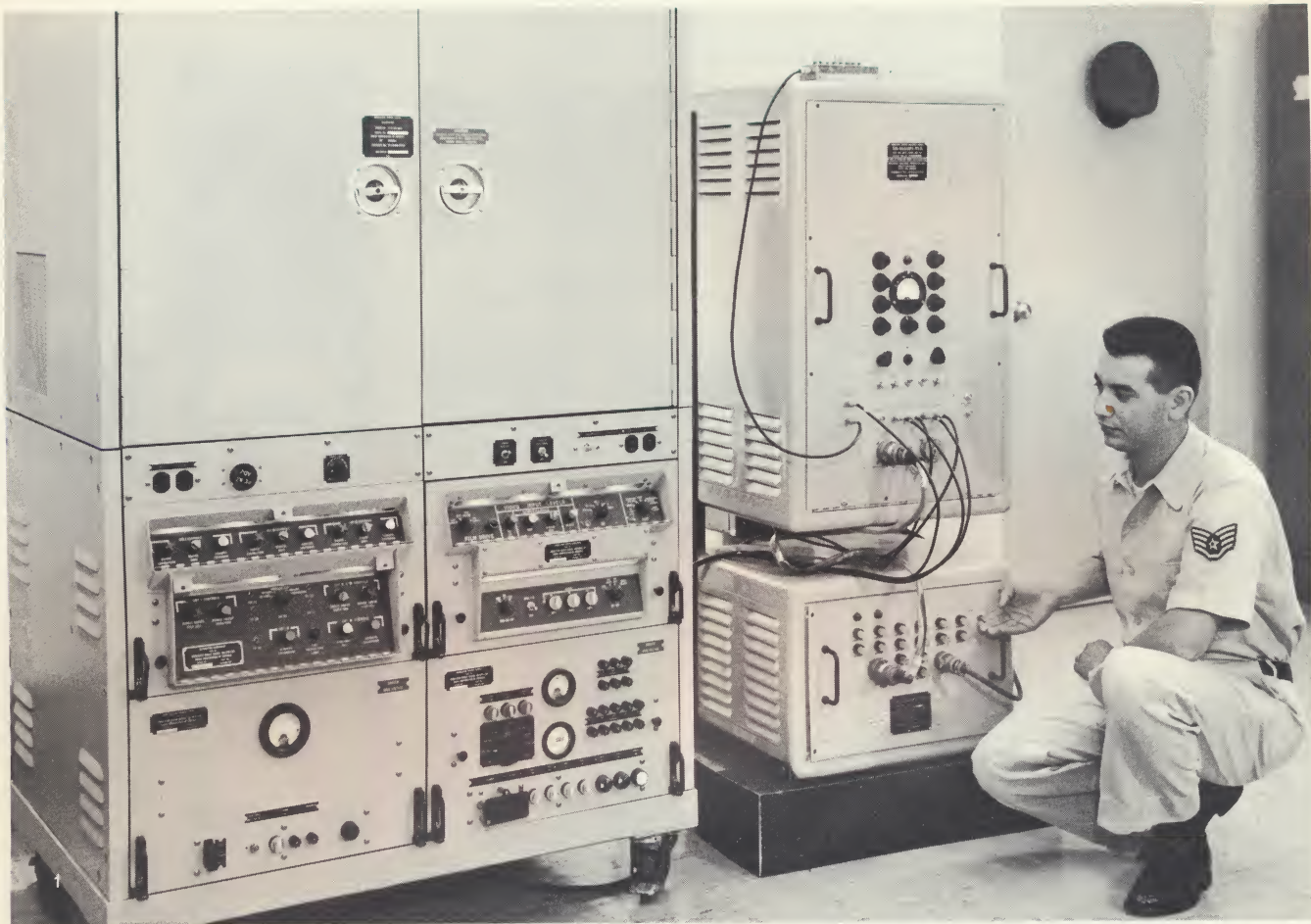


Figure 3—Simulation in the Air Defense System Training Program as it functions in an operational setting.





Simulation equipment is used on-site in the SAGE System Training Program. **Photo 1:** These two machines (AN/GPS-T2B and OA-1767/GPS-T2 ACTER) together can generate a synthetic surveillance radar picture which includes all preprogrammed targets, chaff and radar jamming to be displayed at the site being trained; this synthetic display is representative of the actual picture which could be seen by the site. **Photo 2:** Simulated controllable blips appearing as interceptor aircraft on a radar scope are produced by the AN/GPS-T4. **Photo 3:** A communications jamming simulator can produce jamming signals at any level required for any given time during either live or simulated exercises.



heart of the system. SAGE STP problems were adapted to computer radar inputs by using magnetic tape instead of film. Versatility and economy were introduced by producing simulated problems for large geographical areas that could be used for actively training the system in the entire area, or any single site or combination of adjacent sites. A "library" of individual problems permitted computer-controlled selection of any variety of air traffic in such problems, thus permitting many combinations of simulated situations to be designed by on-site personnel from a single problem source.

#### Site Production System

A logical outgrowth of these and related developments in training was the introduction of the Site Production and Reduction System (SPARS). This system enabled the military user to design and produce his own simulated inputs on site at low cost. In addition, special recording and reduction programs permitted him to automatically collect data to analyze crew and system performance.

The formidable job of designing, implementing, and testing the SAGE computer program, and integrating the program system into the larger operational context, required massive simulation support from many quarters. An Experimental SAGE Sector in Lexington, Massachusetts, was used as a prototype SAGE Direction Center; it was connected to long-range radars and fighter bases. SDC contributed to initial efforts to develop computerized simulation modes for testing specific areas such as alternative automatic tracking logics and the general problems associated with the man-computer interface.

#### Software Testing

SDC developed an extensive software testing effort which required a wide variety of simulation support at all levels of the life cycle of successive models of operational SAGE computer programs and provided critical insights for improving each subsequent generation. Simulation was employed for parameter and assembly testing, and associated checkout (known as "debugging"), of new program models in the design stage at the RSQ-7 facility at SDC in Santa Monica, California. System testing and design verification testing of specific features, involving combinations of simulated and live inputs, were conducted at the Kansas City Air Defense Sector (and later at the Phoenix Sector), prior to field installation of new program models. Simulation, including SAGE system training problems, was extensively used at field sites to adapt the program models to the unique configuration of the local air defense area, as well as to train operational crews.

The simulation activities associated with the life cycle of computer program models covered a broad spectrum ranging from completely automated computer tests to man-computer simulation for functional areas such as tracking or weapons control, to large-scale system tests using field facilities.



Simulation was often a necessity in meeting tight schedules because it permitted the timely demonstration of a satisfactory working system for operational use.

Automated simulation tests of tracking and interception logic have a long history in SAGE and are still actively employed. Some of these tests have used sophisticated statistical, linear programming, and Monte Carlo methods. The unmanned interceptors, such as the Bomarc series, were initially flown through computer simulations developed by SDC, and later, in live prototype field tests they were supported by SDC simulation which provided realistic target inputs and means to assess kill effectiveness.

SAGE system training problems have been extensively used in field operation for tactical evaluation tests (SIM TAC EVAL) and simulated Command Post Exercises (CPX). These partially simulated field operations are supported by a versatile and highly flexible operational recording and reduction system that helps the military user collect and analyze digital data on system performance.

#### System Testing

The sophistication and compelling realism of SAGE system training problems applied to large geographical areas recommended them as credible and convincing vehicles for conducting system tests under highly controlled experimental conditions. For example, an extensive system test was conducted over the entire northeast portion of the United States. This test employed a multi-division SAGE system training problem in a credible combat setting designed in large part by local Air Force officers. Nine Direction Centers and two Combat Centers participated with some 700 military personnel. The test was designed to yield critical data on the relationships between system performance, computer operating time, and system capacity. Because this test was drawn from the available pool of training problems, the simulated test materials did not involve any extra expense for the Air Force. Simulation may thus serve as an economical, omnibus vehicle for training and testing.

#### Regenerative Recording

From these system tests a powerful simulation technique evolved, called regenerative recording. This involves digital recording of initial conditions and subsequent recording of all computer-system inputs. Playback of these recordings into the operational program results in a regeneration of the original computer operation. A rerun results in the same steps taken in the same sequence as in the live test run.

Regenerative recording makes it possible for the military user, programmers, training specialists, or system test personnel to rerun live, simulated, or combined exercises in the computer as often as they wish. Reruns reconstruct the full real-time, real-world, and man-machine complexity of the live computer inputs from the original system test. For example, in one follow-on study of the multi-division system test described above, it was possible to

analyze the 58,000 operator actions taken during the test to help evaluate operator performance. The cost of extracting these actions from the regenerative recordings was trivial. This technique, used in conjunction with operations simulation, permits accelerated design, testing, and training on an economically attractive basis.

The most effective simulation techniques evolved for the manual and SAGE systems are being applied, with some new variations, to BUIC, the third generation air defense system.

#### Strategic Air Command

In support of its design and development responsibilities in the Strategic Air Command Control System (SACCS) project, SDC established a Simulation Facility (SIMFAC) in Paramus, New Jersey. The SIMFAC is a physical model of the SAC Underground Command Post complete with Command/Control personnel stations, capabilities to produce simulated SACCS hardware printouts and wall displays. There is a soundproof observation deck in which SIMFAC personnel perform actions necessary to simulate all external occurrences starting from an Intelligence buildup to changes in threat responses by external commands and actions by all SAC units that are not part of the actual command post. These "Command Post Exercises" utilize completely developed scenarios which depict events requiring SAC responses. It is in this manner that many of the operational design concepts for Command/Control function have been derived and validated.

Part of the SIMFAC is a Human Factors Laboratory in which specific system problems such as symbol identification message input procedures, etc., are investigated. The results of these investigations are used to specify procedures for the operational system. Some of the investigations in the areas of symbol recognition and search times have been of sufficient significance to have been published in the *Journal of Engineering Psychology*.

In conducting project support for the Strategic Air Command, computer programs and procedures have been evolved which permit the rapid generation of alternate complex plans, the simulated execution of these plans, and an evaluation of the utility of each. Designated the APT (Alternate Plans Test) Simulator, (Fig. 4), its three elements perform these sequential functions:

- The Plan Generator is a set of man/machine procedures for very rapidly producing a large number of alternate force utilization plans. A prototype model (for the 1401) has been completed. Operation of the model has demonstrated solutions to the difficult programming problems associated with obtaining flexibility and speed for rapid plan generation.
- The Plan Executor is an event-sequenced Monte Carlo model which simulates the application of plans produced by the Plan Generator.



STAFF  
PLANNER

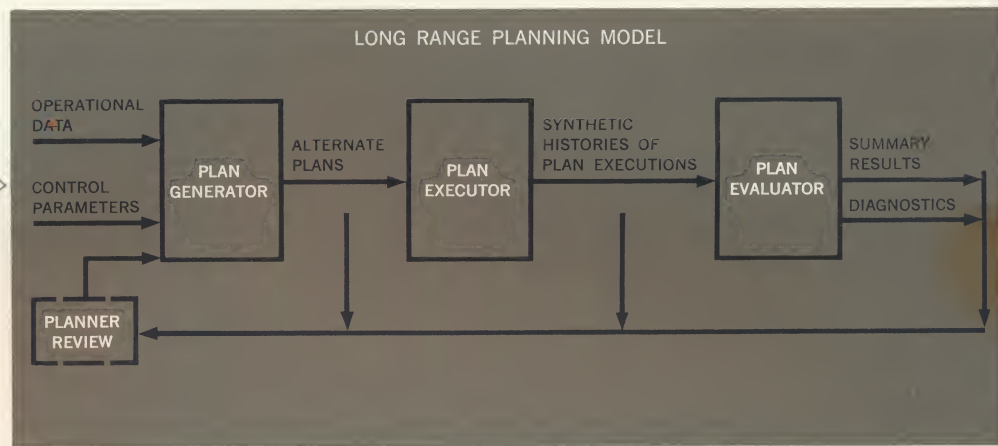


Figure 4—The Alternate Plans Test Simulator.

- The Plan Evaluator provides means for statistically summarizing, analyzing, and diagnosing the outcomes of a simulated plan execution, in order to measure the probable effectiveness of a given set of plans.

As plans are generated, “applied,” and evaluated, it is possible for the human planner to intervene as desired by way of altering procedures, constraints, and objectives. At the prototype level, the APT Simulator is one of the most promising developments in the field of planning. Its principles and techniques are applicable in a great variety of complex planning situations within defense fields as well as elsewhere.

A major contribution to the tools available for data processing system analysis has been developed in the form of a Data Processing System Simulator (DPSS). The DPSS is an extremely flexible general purpose computer program that provides system performance data on a proposed new design or modification to an existing design prior to making equipment selections and commitments or performing any significant computer program design. The total system design including the software and equipment portions can be subjected to a rigorous analysis and evaluation early in the design process so that key decisions can be made in the areas of:

1. The kind of equipment to be used.
2. The number of each type of equipment.
3. The kind of data processing discipline and strategy required.
4. The projected performance of the system under varying loads.
5. The system’s maximum capacity.
6. The system’s ability to respond as a function of loading, capacity, and environment.

The DPSS is complete and operational. It has been used in over 300 runs and has been applied to three different types of command/control systems involving major data processing efforts with a high degree of success. Extensions of the DPSS are in process which will further extend the basic capability into the multi-processing and parallel processing EDP applications of the future.

## Other Major Applications

Additional specific applications of simulation, drawn from the many information processing system development projects for which sdc has had some responsibility for "software" design, may also be cited briefly:

### Command and Control Research

Under contract to the Advanced Research Projects Agency of the Department of Defense, sdc has created a computer-based simulation laboratory for the conduct of applied research on information processing in military command and control. The laboratory contains an experimental command post in which man-machine processes are studied, and improved data-processing techniques and decision-making aids are developed and evaluated. The laboratory realistically simulates operational environments in which techniques can be evaluated in terms of improvement in command and control operations.

### Bio-Medical Applications

Simulation has been applied as a useful tool in sdc's work on the development of computer-based information systems for hospitals. As part of an on-going effort with the U.S. Veterans Administration, the operation of a 60-bed hospital was simulated on a digital computer. This application of simulation served to demonstrate ways in which a computer could be used to maintain patient records and provide scheduling information as well as to generate, upon request, useful reports for patient care and administrative purposes. Lessons learned through this simulation are contributing to the design of a computer-based information system for a VA hospital.

SDC's unique experience in providing simulated environments in which large systems can be exercised to evaluate their operations is also being applied to the problems of Public Health Administration through an epidemiological game. In this game, which involves simulation of the pertinent environment, participants attempt to detect, halt, or meliorate the effects of an epidemic attack on a community.

### Arms Control

SDC has developed a simulation model to study alternative arms-inspection techniques. Designed to simulate the environment of decision-makers, the model permits two or more groups of players, representing nation states, to make critical judgments about their future force structures on the basis of different types and quantities of intelligence about the behavior of other participants.



## NORAD

SDC is currently assisting in the conduct of operational experiments on-site at NORAD Command Headquarters in Colorado Springs. The facility in which these experiments are conducted is a prototype of the automated Combat Operations Center for NORAD and is supplied with simulated inputs for purposes of design verification and system test.

**Photo 1:** In the Command Research Laboratory participants engage in studies of military command and control in a simulated operational environment.

**Photo 2:** Actions of participants in a specific simulated environment provide information to aid research in human decision-making processes.

**Photo 3:** A 60-bed hospital, represented on a computer, permits detailed analysis of patient and hospital information processing.

**Photo 4:** The Leviathan study provides an adaptable simulation procedure for representing a variety of large-group structures.

**Photo 5:** The CLASS facility enables researchers to perform controlled experiments dealing with problems of the use of computers in education.





## Research Activities Employing Simulation

In its extensive program of basic research in the information sciences, SDC has found numerous opportunities to apply simulation. In the Systems Simulation Research Laboratory (SSRL)—an advanced computer-based facility for simulating man-machine complexes—a number of large-scale systems are being simulated for research purposes. Several of these simulations are described below; they range from abstract representations of systems to the faithful replication of real environments.

### Leviathan

An example of abstract systems research is the Leviathan study—an investigation into the structure and dynamics of large groups. By changing the mythical environment in which these experiments are embedded, Leviathan can represent a wide array of systems: an intelligence center, a command headquarters, a government bureau, or any other complex group. In Leviathan, live subjects in the laboratory communicate with each other, and give commands to as many as 1000 automated operators (computer-simulated people), all via the computer which displays and records their “actions.” Through methodical variation in experimental parameters, Leviathan is investigating questions of policy formation, strategy, communication, and other command interactions.

### CLASS

An example of a completely lifelike model is SDC's automated classroom of the future. Designated CLASS—for Computer-based Laboratory for Automated School Systems—this permanent facility within the SSRL contains closed-circuit TV, students' desks equipped with audio devices, film viewers, and response devices, special-purpose teacher display equipment, and a computer-assisted counseling facility. Using students from local school districts, SDC's education research team is probing into problems of programmed learning and automated assistance to education, with the long-range goal of developing more effective means of instructional support. In CLASS, as in Leviathan and the Terminal Air Traffic Control study, subjects soon forget that they are in a simulated facility and produce the real, live, and natural responses that are crucial to good research.

In addition to the examples of operations simulation described above, each of which involves construction of certain physical aspects of the system, many research investigations utilize algorithmic simulation, in which the modeling takes place entirely within a computer. This research includes the modeling of a management control system of more than 20,000 instructions, a flexible school capable of a variety of configurations, selected aspects of biomedical systems, and various cognitive processes designed to solve problems, answer questions, recognize patterns, and display creative intelligence.



## Projections

A technique so well mated to the nature of digital computation as simulation seems assured of a busy and useful future. Under the circumstances there is little risk in projecting several of the major directions further development of this technology may take.

### Gaming for Training

Simulation gaming has, in recent years, broadened beyond its former somewhat esoteric uses in operations research to become a highly practical training medium for executives and other senior personnel.

These gaming techniques have only begun to be tapped for their practicability, flexibility, and power.

### System Design

Simulation has been used as a practical and economic tool in the system design process. Too often, however, it is still considered to be impractical—in the sense of being too limited—for such purposes.

In point of fact, the very complexity and the development time of future systems will call increasingly for the use of simulation in design. It is not difficult to foresee the possibility of producing alternative system designs largely through prepared programs—even to the point of singling out components or areas requiring entirely new design approaches.

The possibility of automating large portions of standard product design (such as that for a new model automobile) may be only a few years away.

Surely simulation will be a major working tool in the process of evaluating configuration alternatives.

### Hostile Environments

There are still more critical potential areas for the application of simulation. A prime example is the simulation of hostile environments before they must

be experienced. Heat, cold, speed, vacuum, and depth are all conditions that require very sophisticated simulations. This need will continue and expand. Space and space-bodies provide hostile environments; a new, widespread virulent disease would present a very hostile change in our normal environment; a world heavily dominated by alien philosophy is yet another kind of change in environment. The power of operations simulation in exploring these kinds of environment problems and in preparing to cope with them has yet to be realized.

#### First-Time-Perfect Missions

A second critical potential area for operations simulation is in helping to insure the success of missions whose first attempt must be successful. Future space explorations provide dramatic examples. The principles, practices, and techniques of system training (based upon the technology of simulation) provide system exercising and checkout capabilities of inestimable value for these first-time-perfect requirements. The potential role of system training and checkout, coupled with operations simulation, may be as worthy in ground support and control systems for space operations as they have been (and are today) for air defense.

#### Planning

One of the most intriguing prospects for the future of simulation is its almost ideal characteristics as a planning vehicle.

Simulation principles can be applied to operational planning, long-range planning, corporate, urban, or defense planning—in fact, most varieties of planning. There are obviously great possibilities inherent in the APT (Alternative Plan Test) Simulator. In addition to speed, flexibility, and realism, it provides a means of eliminating the costly effects of assessing and adjusting changes in plans (yet thoroughly evaluates changes), all on a real-time operating basis in support of executive functions. Thus, the future for planning can be more practical and vital than ever before—through the improved use of simulation.

#### Real-time Management Aid

Perhaps the most extensive future use of simulation yet remains for identification: as a real-time aid in the support of operations management. In five or ten years it may not be unusual for an executive to have fingertip-access to a pertinent, always-current array of simulated inputs so that he can mix any choice of possible condition changes with real circumstances, evaluate the mix (again by use of simulation techniques), and select actions which are underpinned by clearly understood assumptions.

As these and other new avenues of simulation unfold, both in the laboratory and in the field, SDC will continue to play a prominent role in the forefront of the technology.





---

Corporate Offices:	2500 Colorado Avenue, Santa Monica, California 90406
Air Defense Division:	2500 Colorado Avenue, Santa Monica, California 90406
	Liaison Office: 1719 E. Bijou Street, Suite 1030, Colorado Springs, Colorado 80909
Command Control Division:	45 Hartwell Avenue, Lexington, Massachusetts 02173
	SACCS Department: 567 Winters Avenue, Paramus, New Jersey 07652
Development Division:	2500 Colorado Avenue, Santa Monica, California 90406
	Dayton Facility: 26 West Nottingham Road, Dayton, Ohio 45405
Washington Division:	5821 Columbia Pike, Falls Church, Virginia 22041
Washington Office:	1725 Eye Street, N.W., Suite 702, Washington, D.C. 20006

---

System  
Development  
Corporation

Technology  
Series

